# U. S. ARMY 64-3
# TRANSPORTATION RESEARCH COMMAND
# FORT EUSTIS, VIRGINIA



TRECOM TECHNICAL REPORT 63-51

## RETRACTING THE FULTON SKYHOOK YOKE ON ARMY TYPE CV2B (CARIBOU) AIRCRAFT

FEASIBILITY STUDY

Task 9R96-11-001-02
Contract DA 44-177-AMC-891(T)

May 1963

**prepared by:**

ROBERT FULTON COMPANY
Newtown, Connecticut

4215-63

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HEADQUARTERS
U S ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

This study was conducted to investigate the feasibility of a retractable yoke for the purpose of concealing the mission of the aircraft on which the yoke was installed. It can be concluded that it is feasible to retract the sky yokes.

The scope of the work reported did not include any analysis of the cost, weight, or effect on aircraft performance. It is believed that these aspects should be investigated prior to the selection of any of the configurations for construction and test.

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# RETRACTING THE FULTON SKYHOOK YOKE ON ARMY TYPE CV2B (CARIBOU) AIRCRAFT
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FORT EUSTIS, VIRGINIA

CONTENTS

## ILLUSTRATIONS

## SUMMARY

This report covers the results of a study conducted under Contract DA44-177-AMC-891(T) for the U.S. Army Transportation Research Command (USATRECOM).

When fitted with Fulton SKYHOOK equipment, the Army's Type CV2B (Caribou) aircraft possesses an in-flight pickup capability. A standard part of this equipment consists of a yoke, or V-shaped fork, rigidly mounted on the nose of the aircraft.

The purpose of this task (Number 9R96-11-001-02) has been to study the feasibility of installing a retractable yoke in lieu of the fixed one.

Design considerations were studied, and the results showed that such a yoke could be constructed. Of five possible designs, one showed considerable promise and is recommended as the most favorable.

## RECOMMENDATIONS

The results of this study show that a retractable yoke for the Fulton SKYHOOK can be produced. The next logical step is to design the specific hardware and to construct and test the basic concept.

In the design and construction of a retractable yoke, particular attention must be given to the matter of vibration. This is a function of mass, section, length, airflow, and natural frequency of the members. Some mathematical, analytical work can be done in this regard, but the final proof of the design invariably comes with construction and testing of an actual unit.

Perhaps the safest way to flight test such a unit as this is to construct it on only one side of the aircraft. Thus if any difficulty were encountered during test flights, the engine on the yoke side could be feathered and the plane safely returned to base. Since the two sides of the yoke are totally independent of one another, such a test procedure is perfectly feasible and doubly safe.

# INTRODUCTION

The Fulton SKYHOOK System provides a capability whereby men and materials can be picked up from the ground (or water) by a fixed-wing aircraft in flight. This is accomplished in the following fashion:

The load to be picked up is attached to a 500 foot lift-line which is suspended below a balloon. An aircraft equipped with a "yoke" on its nose intercepts the lift-line near the top, the line locks to the airplane, and the load rises slowly and arcs to follow the plane's direction of flight. Due to the geometry of the system, the acceleration force is low and the trajectory is almost vertical for the initial 150 to 200 feet.

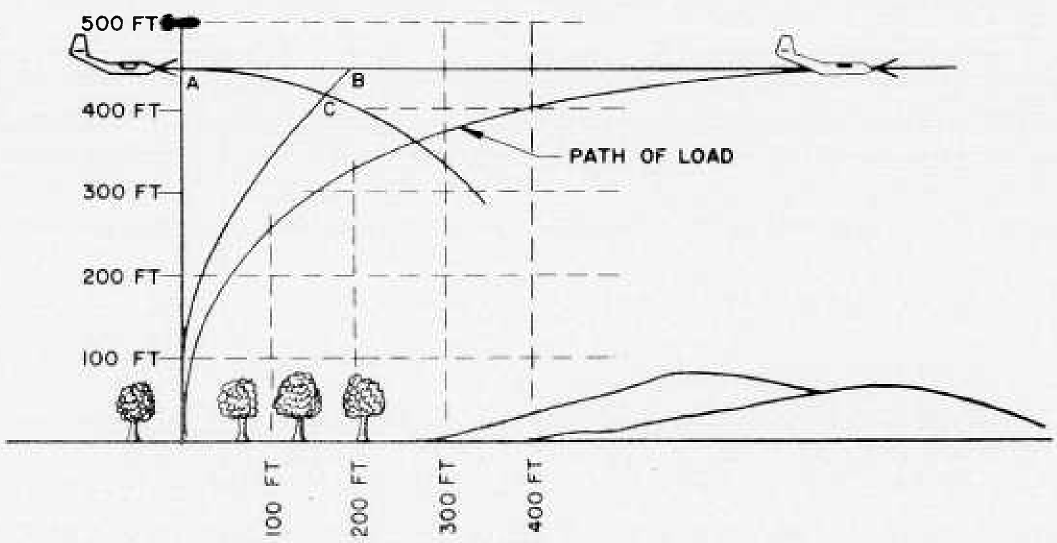



Figure 1. Geometry of the Fulton SKYHOOK System.

During the time the aircraft flies from A to B (See Figure 1.), the load travels only the distance from B to C. Thus, acceleration is very gradual.

Since the lift-line can only pull, the load rises almost vertically, gradually curves and follows the aircraft and is winched aboard.

This pickup system was first tested in 1954. It has since been developed to an operational status and was recently successfully installed on a U.S. Army Type CV2B (De Havilland "Caribou") aircraft.

The purpose of the study discussed in this report has been to determine the feasibility of replacing the present fixed-type yoke on the Caribou with a folding or retractable type. This would have the advantages of (a) minimizing air drag and (b) making the yoke inconspicuous.

## DESIGN CONSIDERATIONS

In approaching the design problem, it is necessary that certain considerations be firmly kept in mind.

First, the yoke is essentially no more than a guide to feed the intercepted lift-line into the skyanchor which locks onto it and accomplishes the actual pickup. The yoke carries no weight except its own.

Second, the wider the opening of the yoke, the easier it is for the pilot to accomplish the intercept. The present Caribou yoke is 26 feet wide. It should not be reduced to less than 23 feet.

Third, it is possible, though rare, for the pilot to miss the intercept. When this occurs, it is (a) desirable to have a deflection-line running from the yoke tips to the wing tips to enable the lift-line to remain attached to the balloon, simply diverting it around the aircraft so that the pilot can come back around for the pickup, or (b) mandatory to have a cutter-line from the yoke tips to the wing tips to insure that the lift-line will be cut and will fall free to the ground without danger of fouling in the propeller.

Fourth, vibration is the controlling structural design consideration. If the unit is strong enough not to flutter or vibrate, it is inevitably more than strong enough to perform its primary purpose of guiding the lift-line into the skyanchor.

Fifth, any design to be satisfactory must be simple (almost primitive) in its concept and execution or it will not be practical.

Keeping the above considerations in mind, the five designs described in this report appeared to have the greatest promise.

## DESIGN ARRANGEMENTS

### CURRENT FIXED YOKE ARRANGEMENT

Figure 2 illustrates the current fixed yoke arrangement. It is included to provide a direct comparison between the size and appearance of the fixed-type yoke and the newly proposed designs.

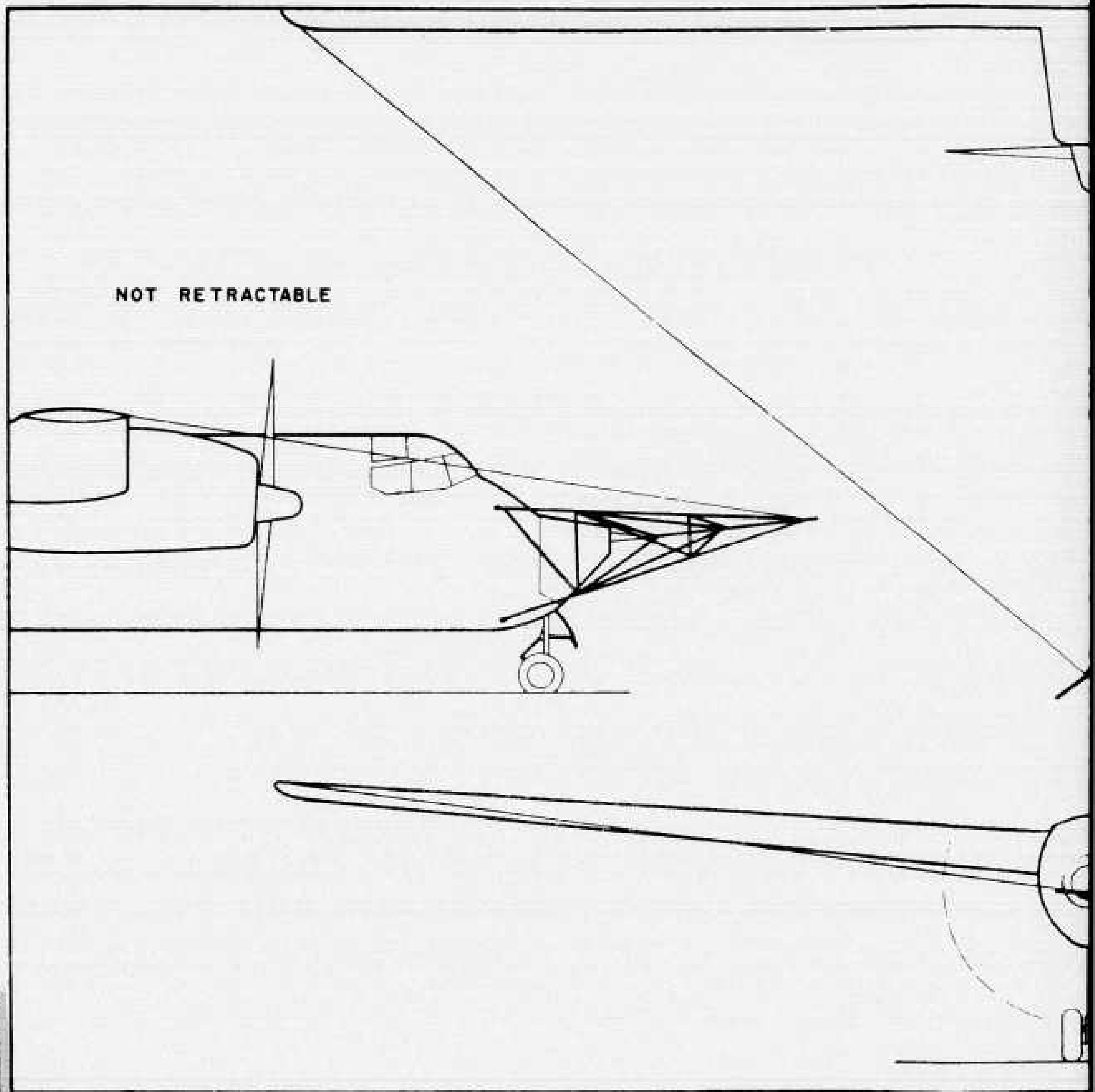
It is emphasized that none of the drawings provides a realistic picture of the appearance of any of the arrangements. In nature one sees shades and shadows, not lines. The accompanying illustrations are line drawings. To be "artful", the lines (and thus the whole yoke) could be made to disappear against the aircraft, but that would not do much for showing the design. The viewer will have to use his imagination and, by making comparisons with the accompanying fixed design, attempt to visualize the extent to which the new arrangements represent an improvement.

It should also be remembered that with Arrangements A, B, C, D, and E only the retracted silhouette will be seen except during the actual pickup operation. For best comparison, cover up the extended side.

### ARRANGEMENT A

The principal feature of Arrangement A is its double use of a deflection-type line. If a line can satisfactorily be employed to deflect the lift-line around the wingtip when the pilot misses his intercept, why cannot a similar line be used to guide the lift-line into the skyanchor at the apex of the yoke? Figure 3 illustrates Arrangement A and its guide-line principle. The guide-line would merely be an extension of the deflection-line.

Since the line will obviously change in length going from its retracted to its working position and since it is imperative that it be taut in order to deflect the lift-line, a constant-tension reel will be mandatory (probably located in the wingtip).

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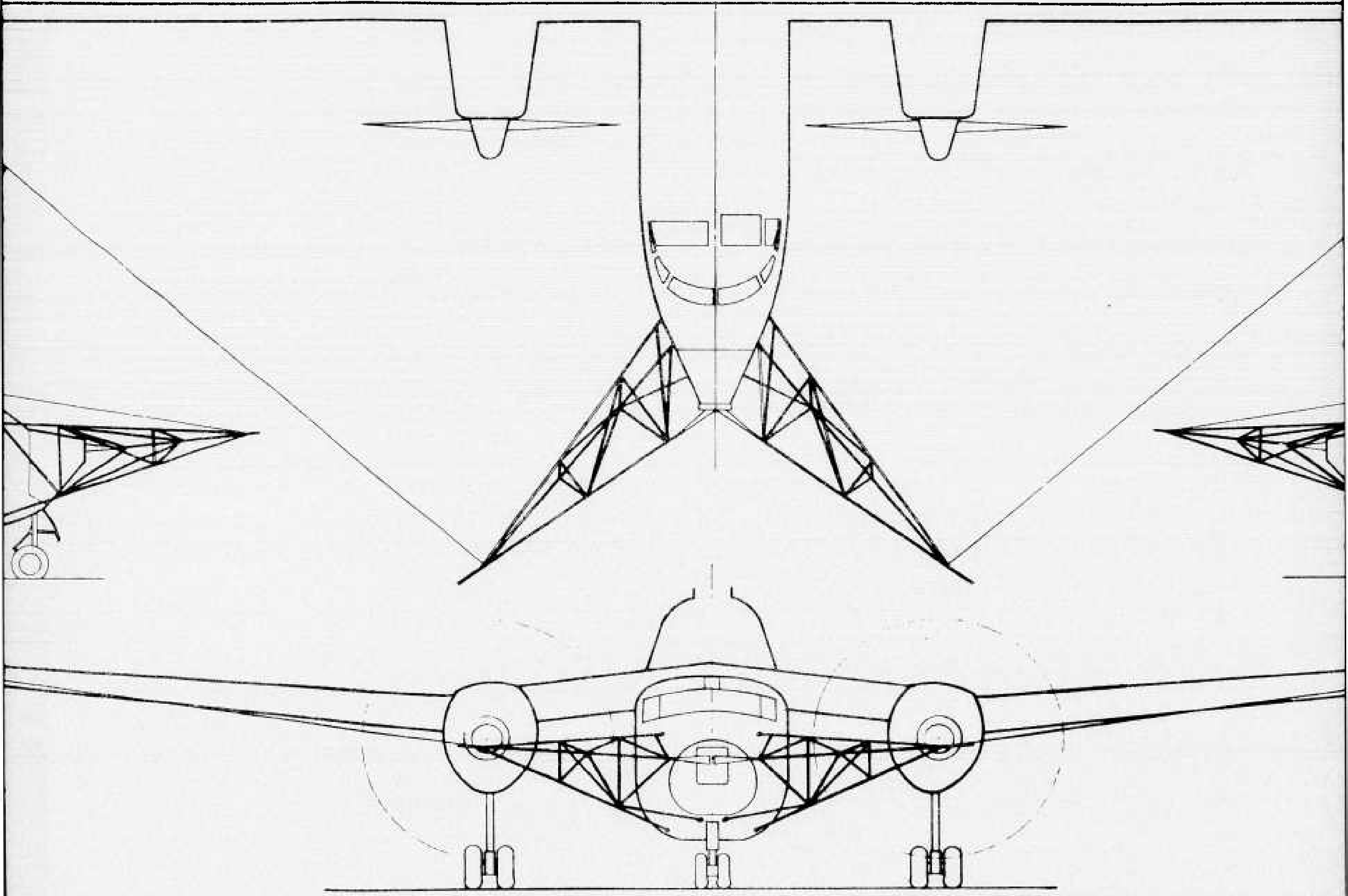

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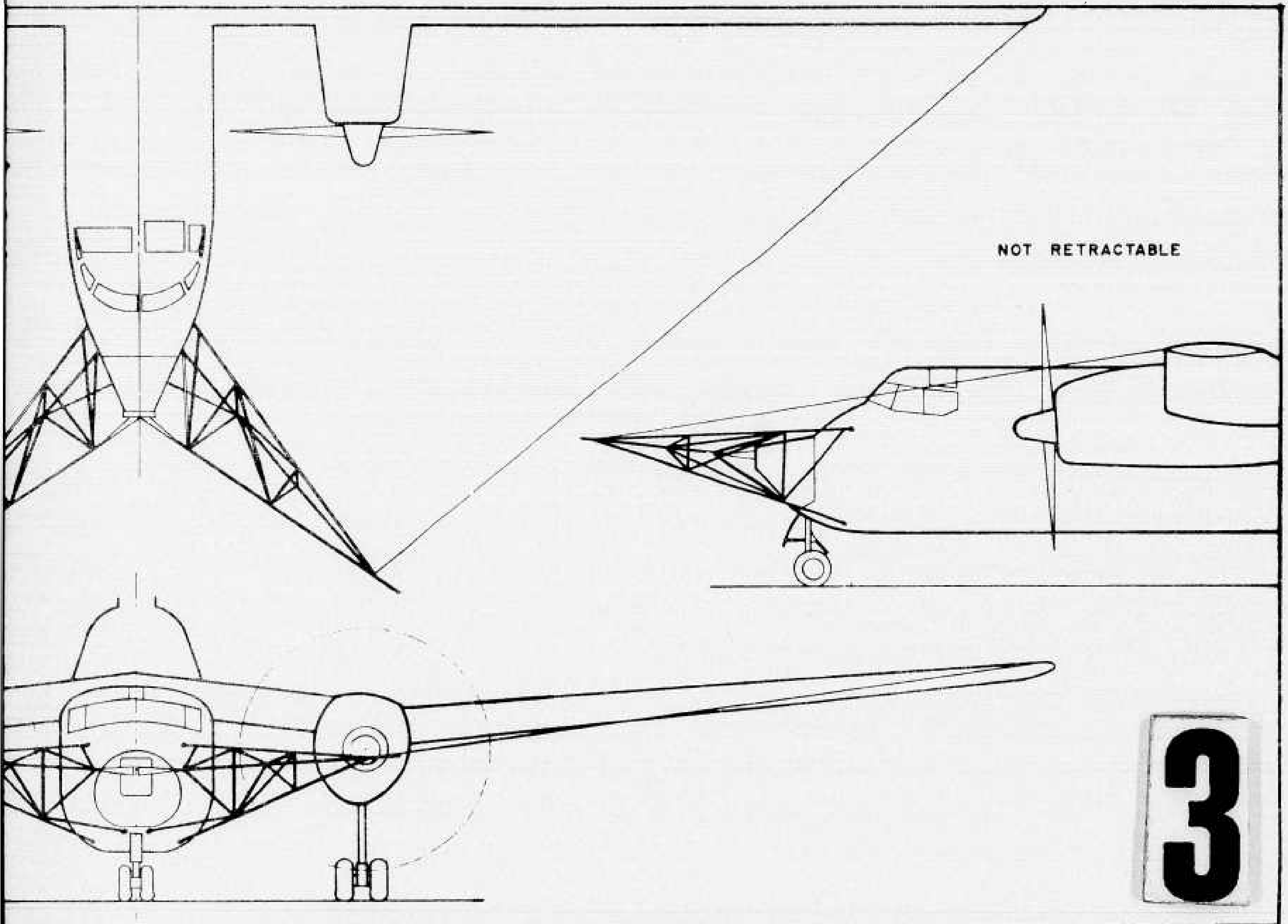
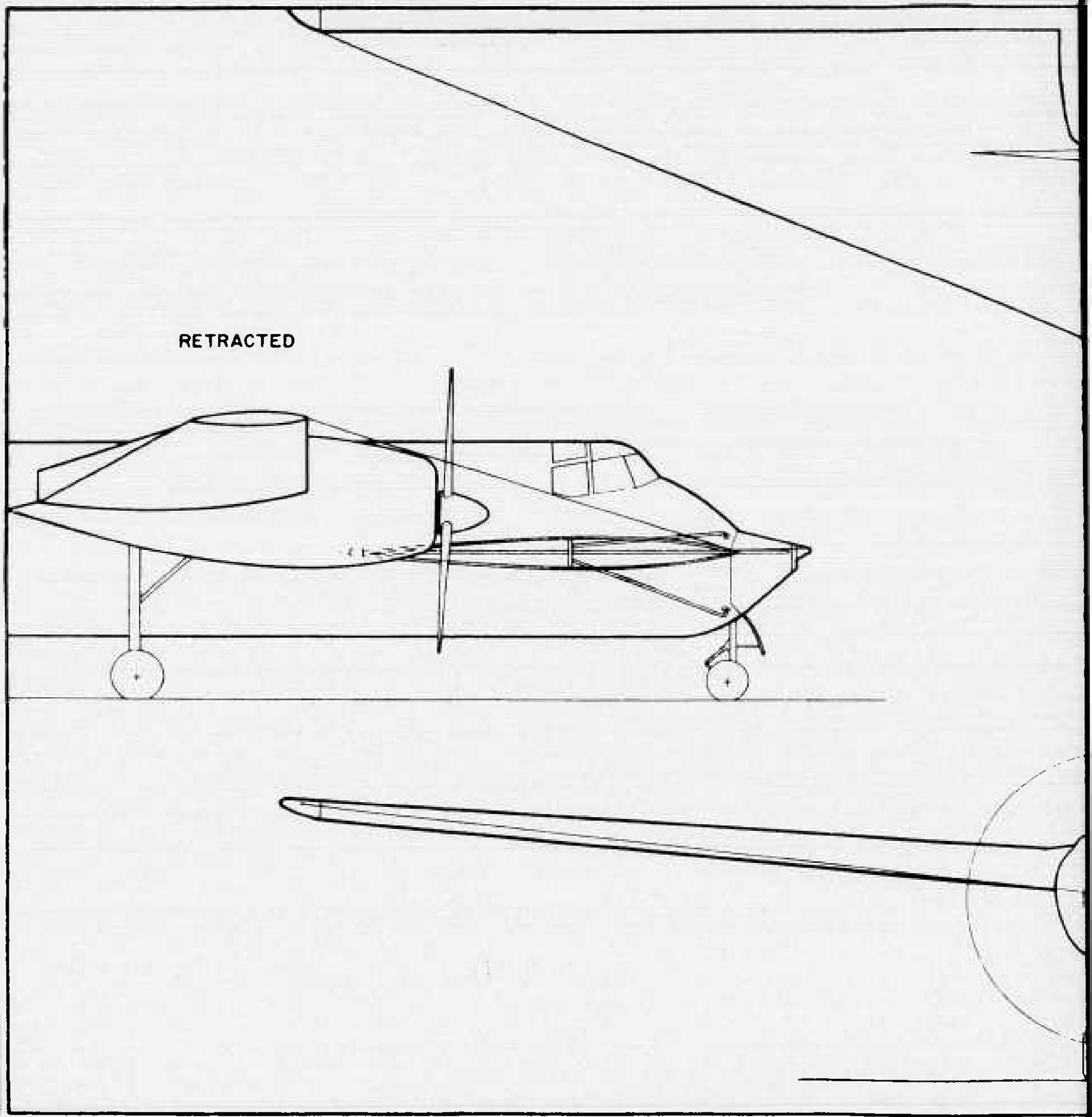



Figure 2. Current Fixed Yoke Arrangement.

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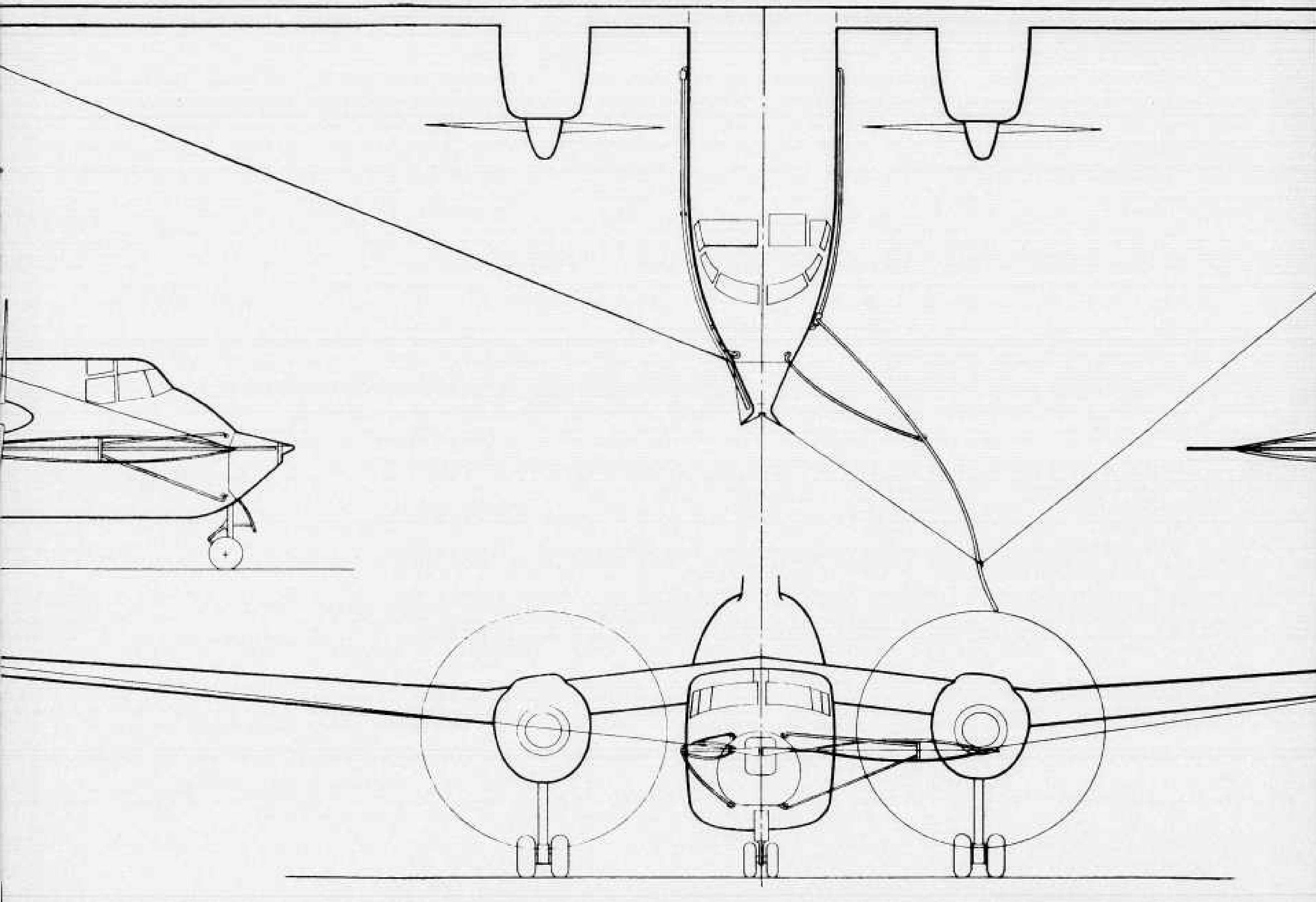

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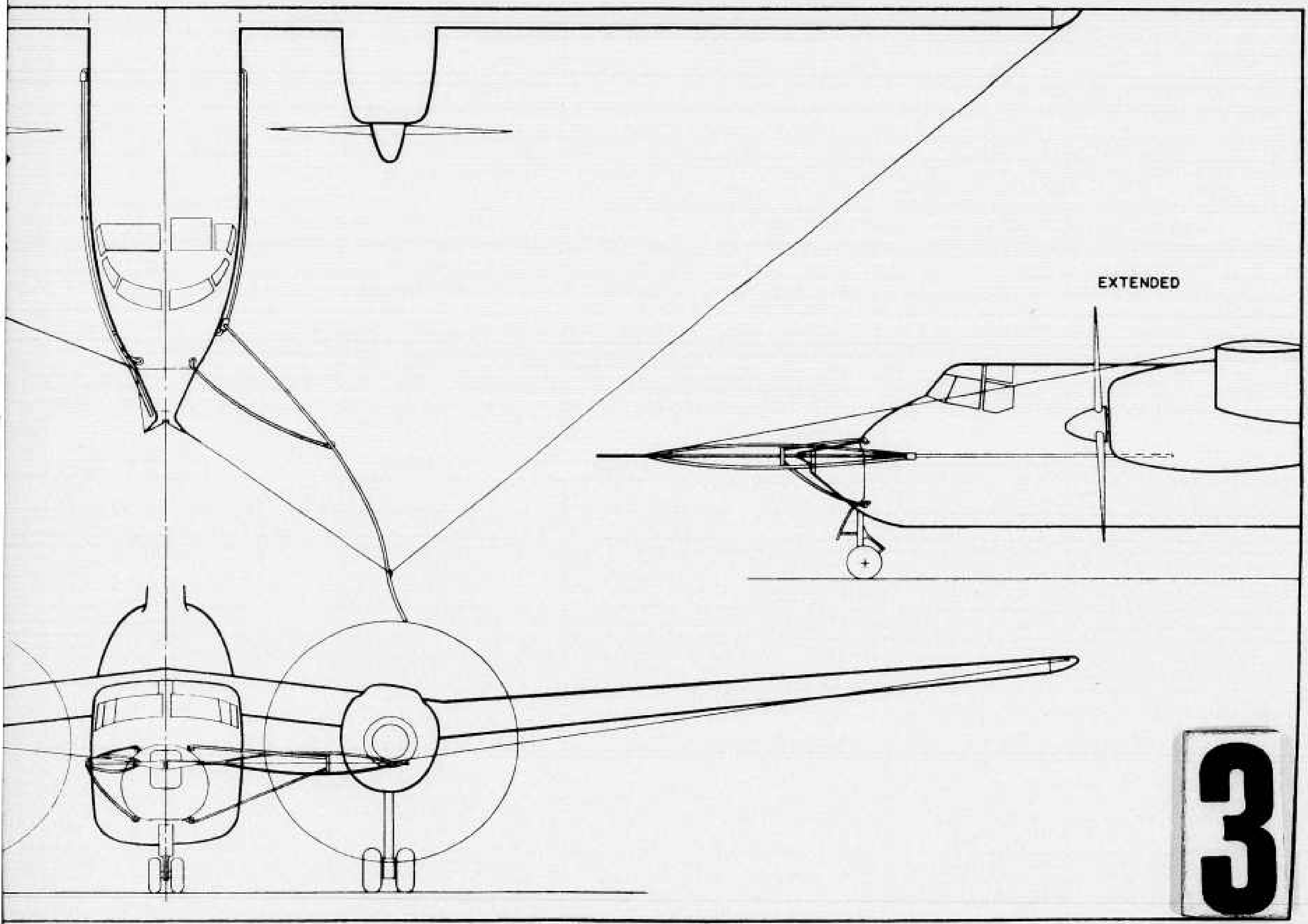



Figure 3. Arrangement A.

## ARRANGEMENT B

Arrangement B substitutes a rigid member for the double-acting deflection-line and adds a tube to the nose to guide the lift-line into the yoke. Otherwise, it utilizes the same basic mechanism as Arrangement A. Figure 4 illustrates Arrangement B.

## ARRANGEMENT C

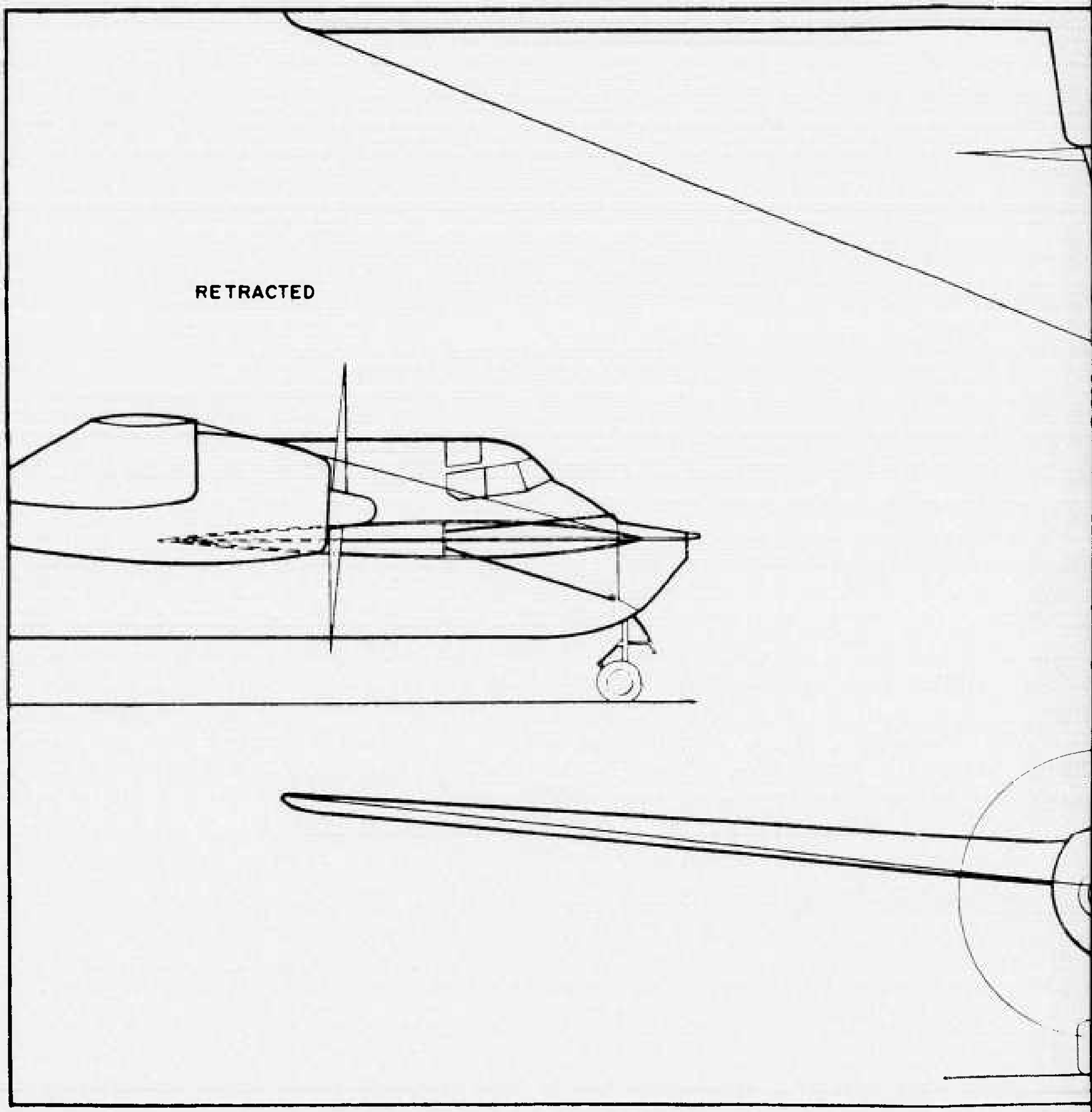
Figure 5 shows Arrangement C which includes a double-track carriage to support the swinging yoke arm. It employs a double-acting deflection-line similar to Arrangement A.

## ARRANGEMENT D

In Arrangement D, the forward yoke member is not only a solid member but is also pivoted at the skyanchor end ( on the nose of the aircraft).

Instead of deflection-lines to the wingtips, cutter-lines are permanently attached, eliminating need for the constant-tension reels. See Figure 6. When the pilot misses the intercept, the lift-line is promptly cut by the cutter-line, thus preventing its reaching the propeller, and the survivor must then erect another balloon station.

This could be eliminated by affixing a sail track to the back of the forward yoke member and rigging the deflection-line to it with a halyard to run it in and out. The geometric relationship between the yoke and the wingtip unfortunately is not such that a wide enough yoke results if the wingtip is taken as the center of an arc passing through the nose of the aircraft. Thus, the length of the deflection-line will change as it moves in or out and the constant-tension winch will again be necessary.

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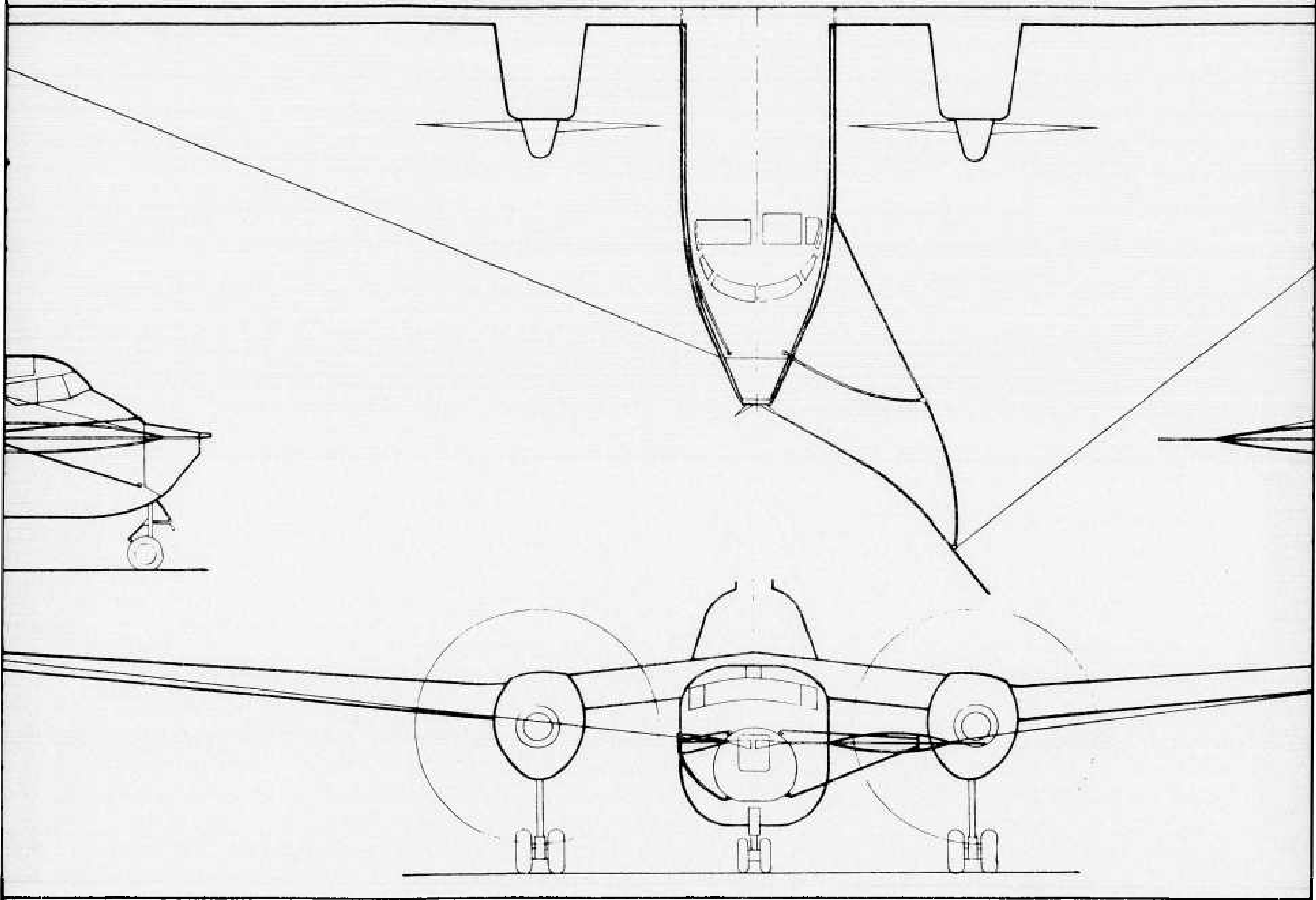

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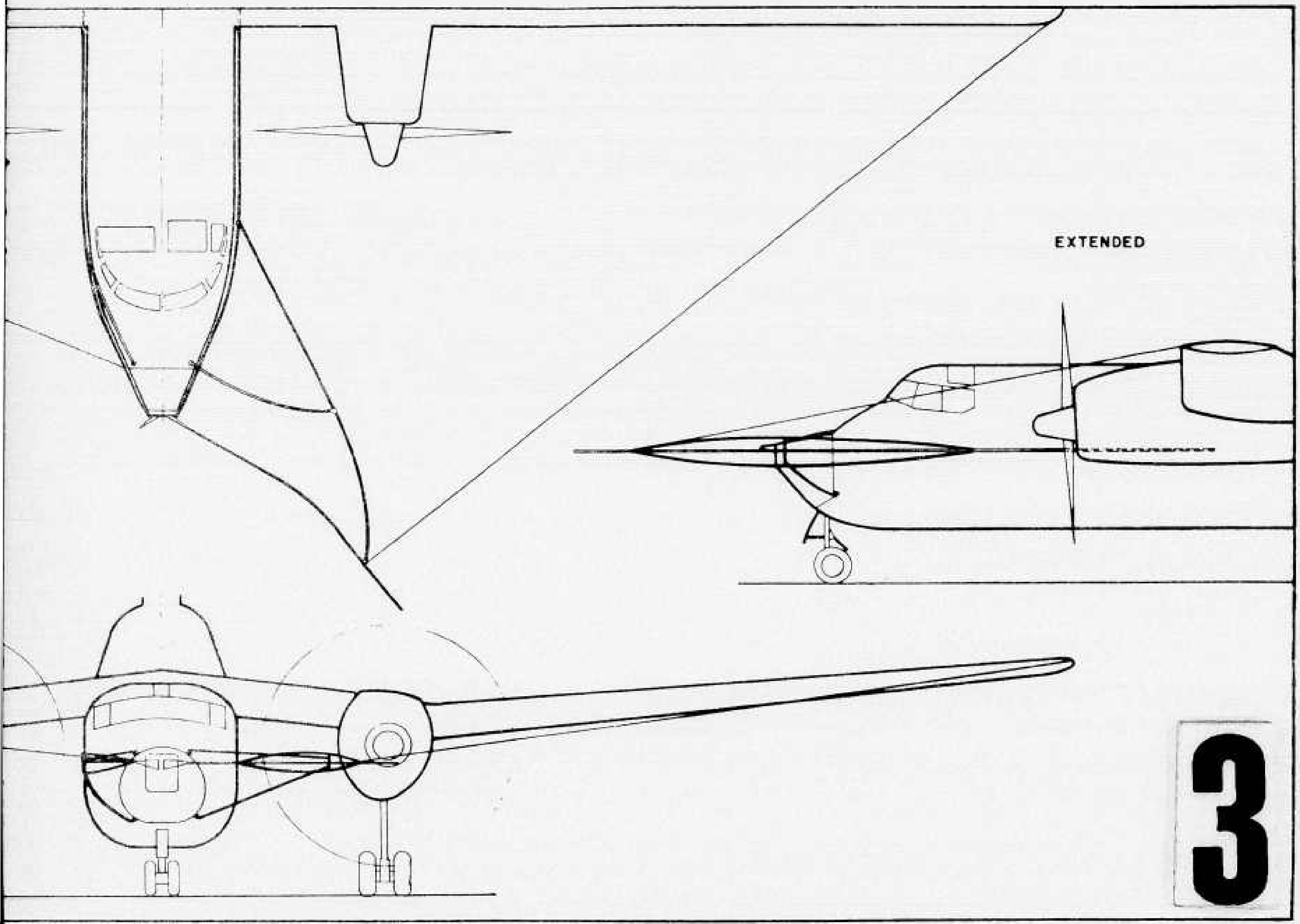
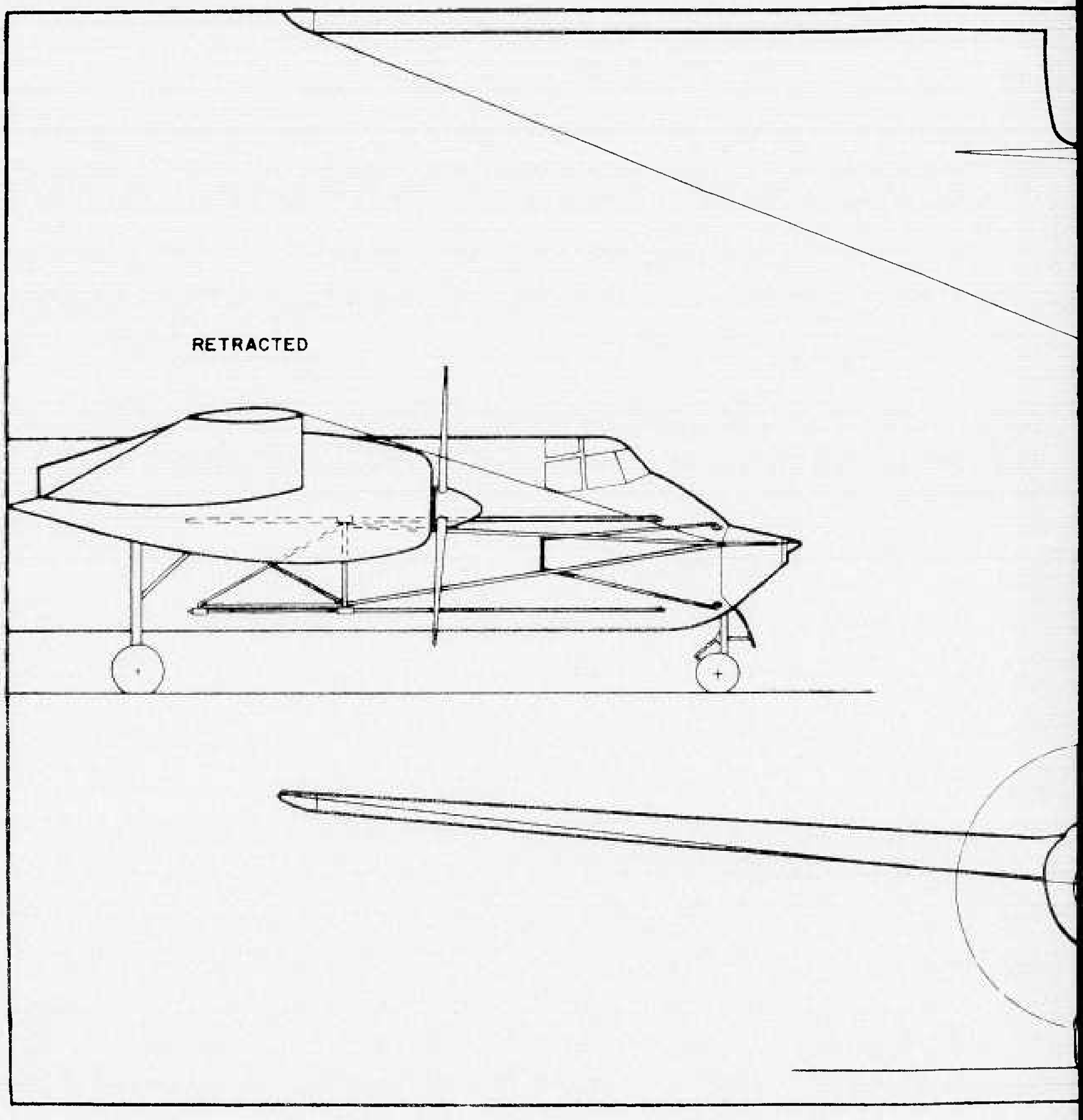



Figure 4. Arrangement B.

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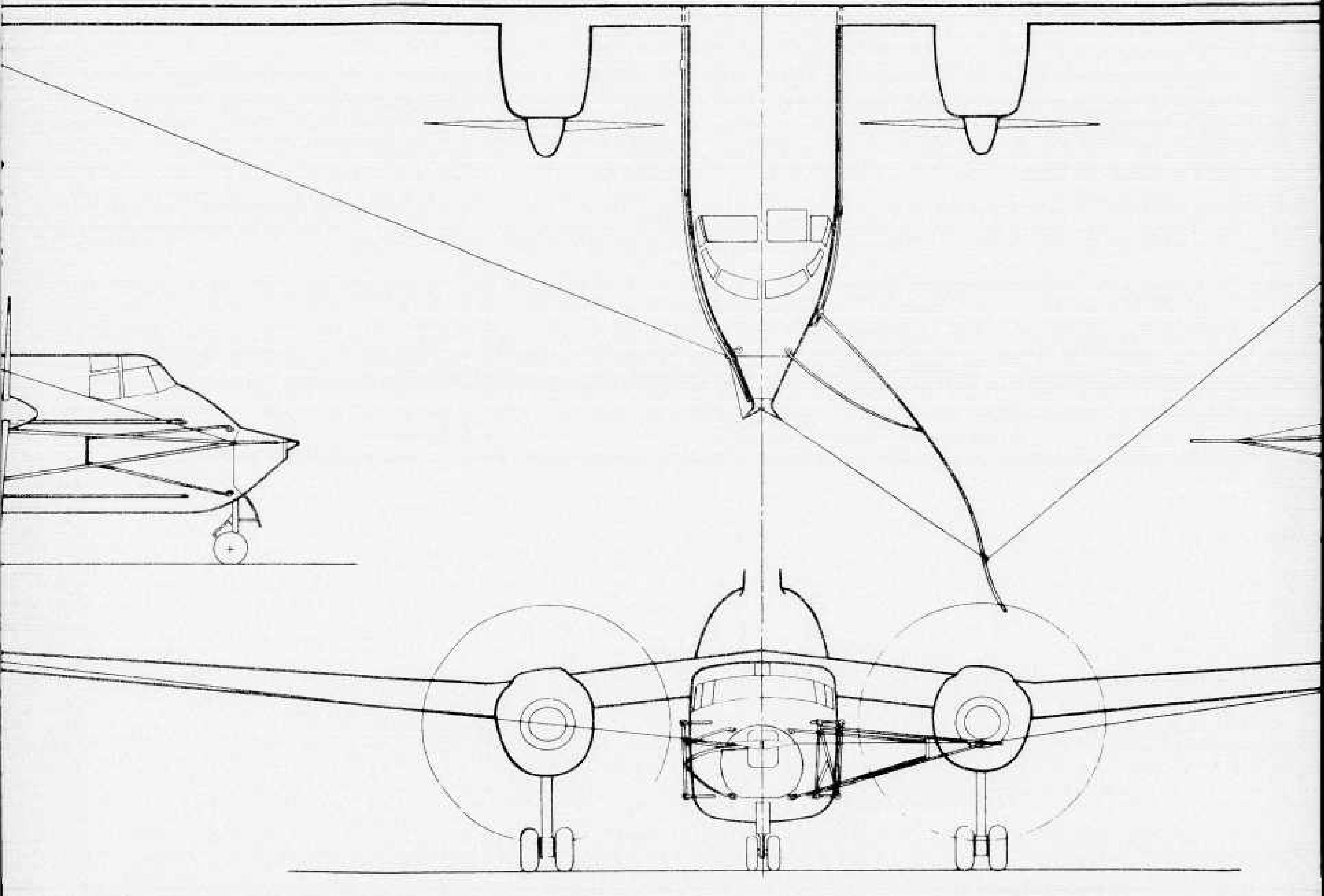

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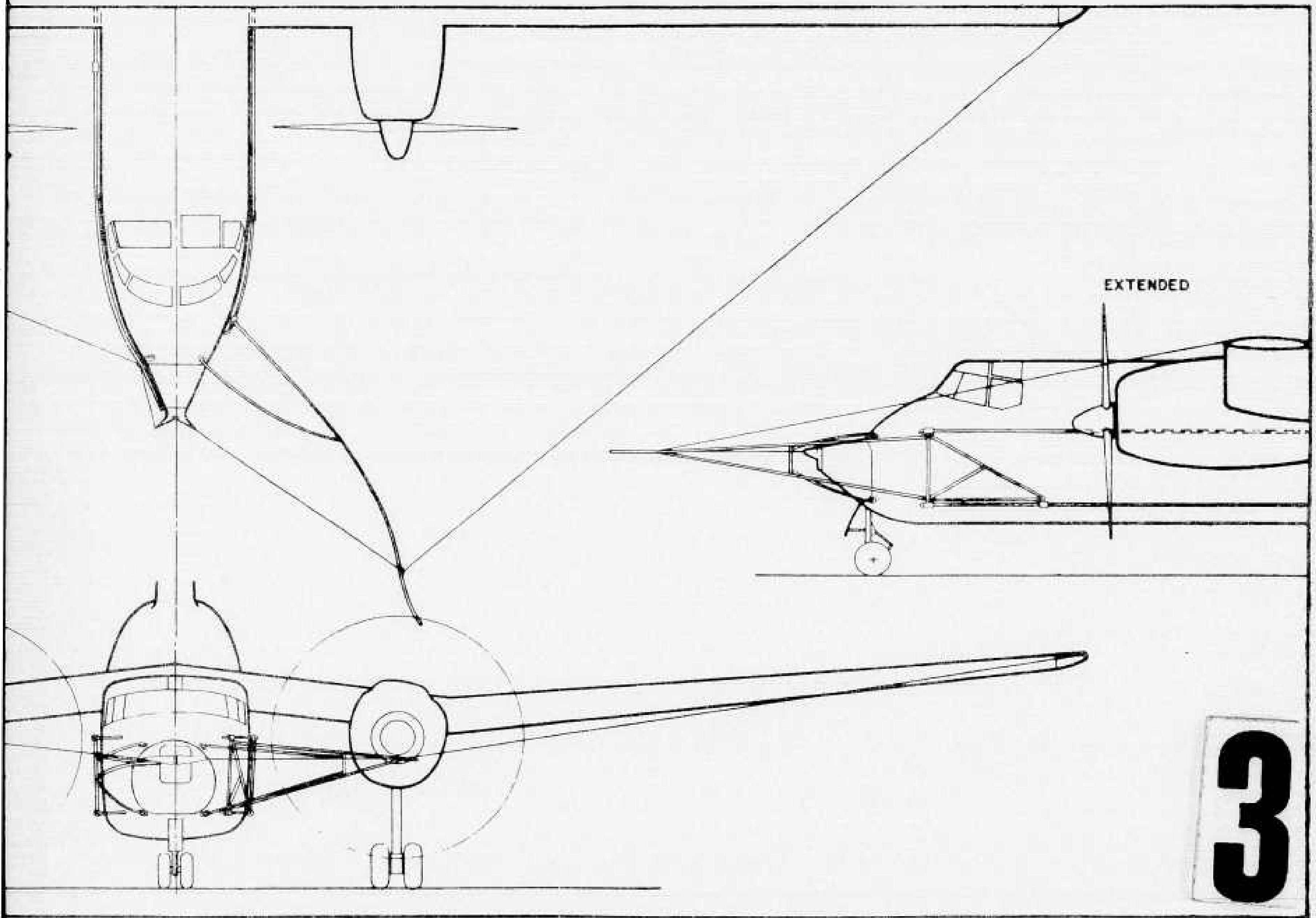
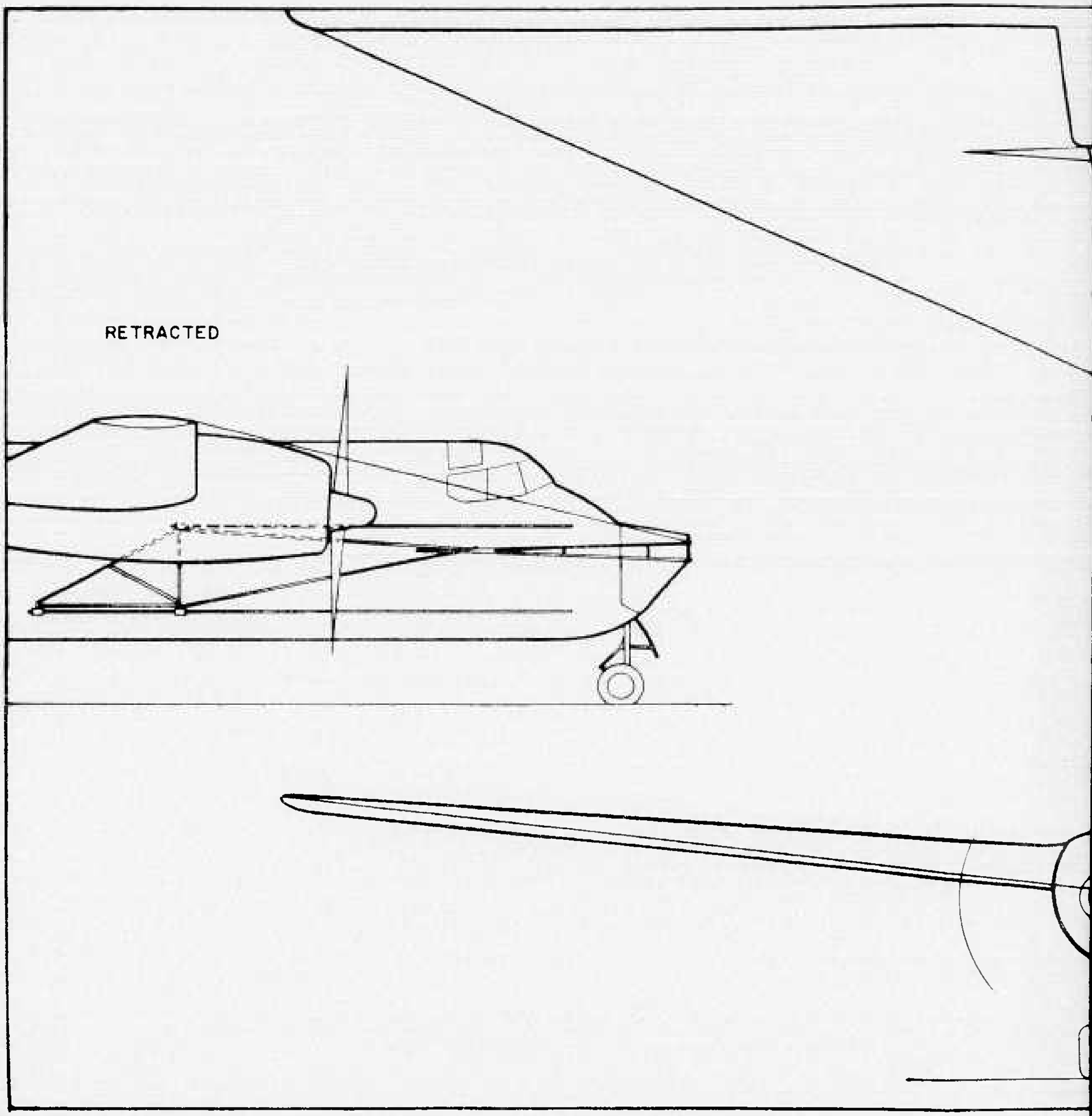



Figure 5. Arrangement C.

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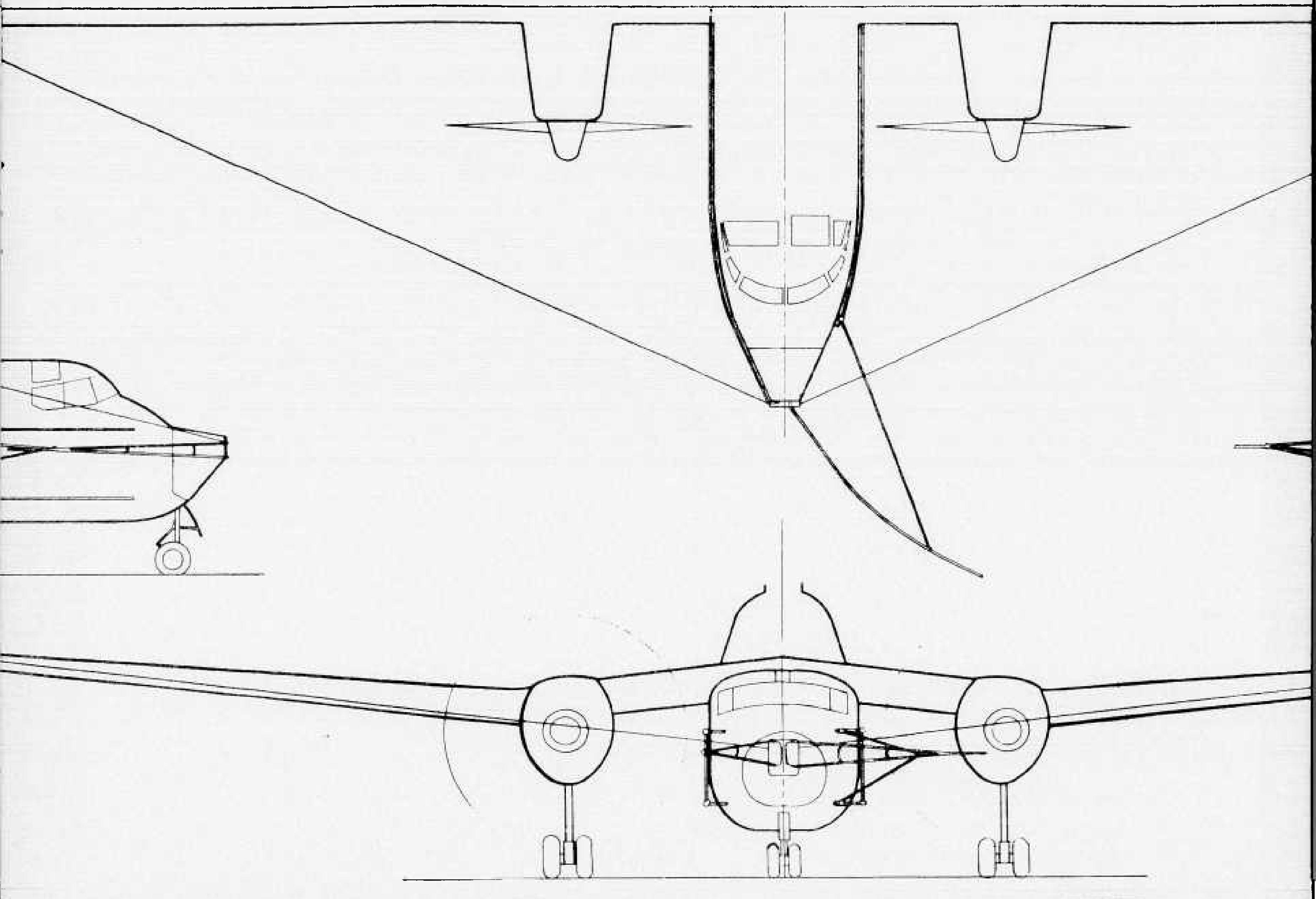

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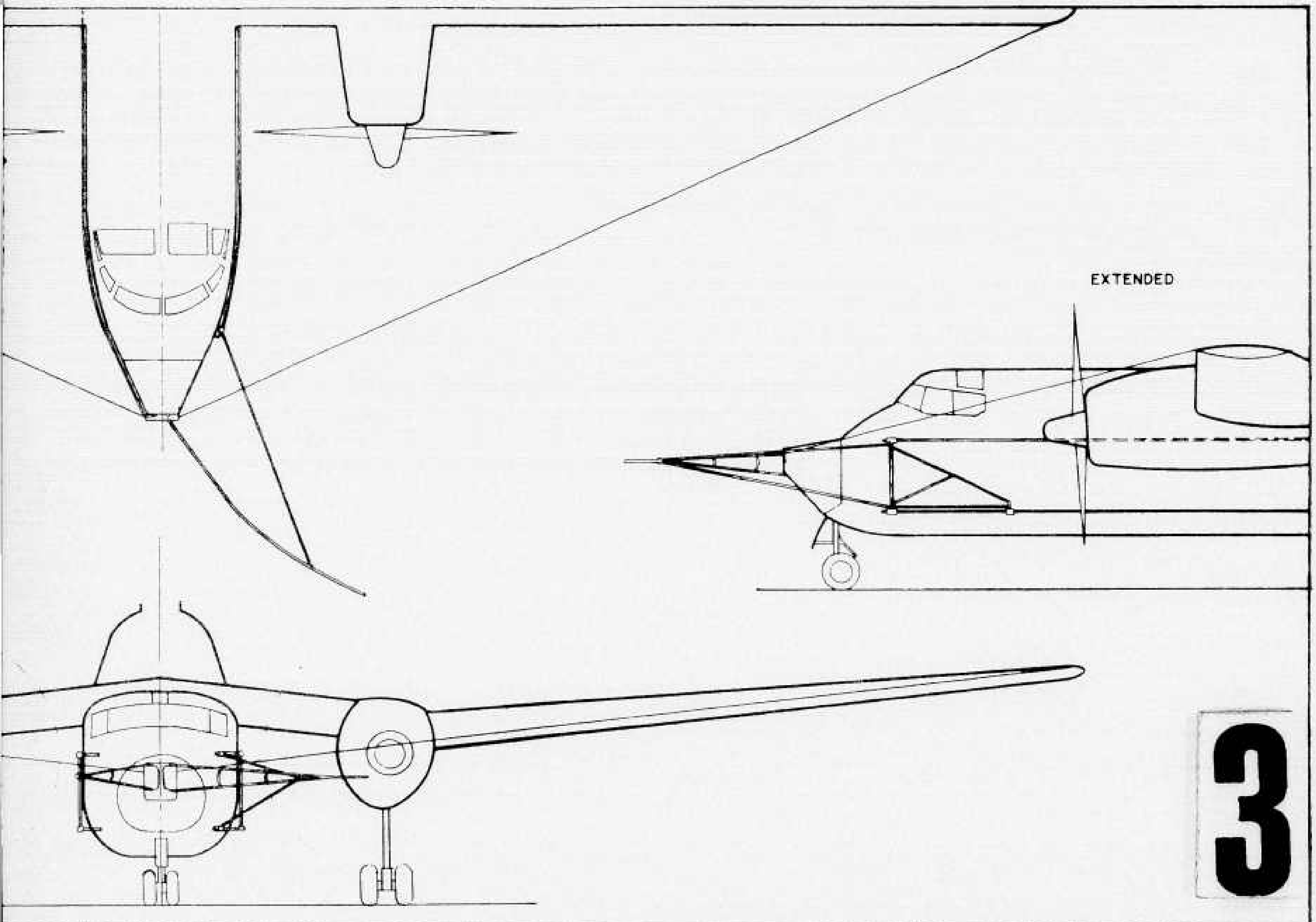



Figure 6. Arrangement D.

## GENERAL DESIGN NOTES

There are several ways to design the rails and carriage, to drive them, and to provide the constant-tension necessary for the deflection system. Figures 7, 8, and 9 show examples of a rail and carriage mounting arrangement, a carriage drive system, and a constant-tension deflection-line winch. These illustrations are examples only.

It is assumed that construction throughout will be welded steel tubing 4130 chrome molybdenum or equivalent. Wherever the design would be enhanced (and there would be quite a few places), the tubing will be streamlined. In some instances it may even be worthwhile to manufacture tapered streamlined sections.

Since the yoke will be retracted at all times except during pickup operations and since these will be performed at low airspeed (125 knots and below), the extended installation will not be called upon to cope with Vmax conditions. This is a considerable advantage in keeping the design simple.

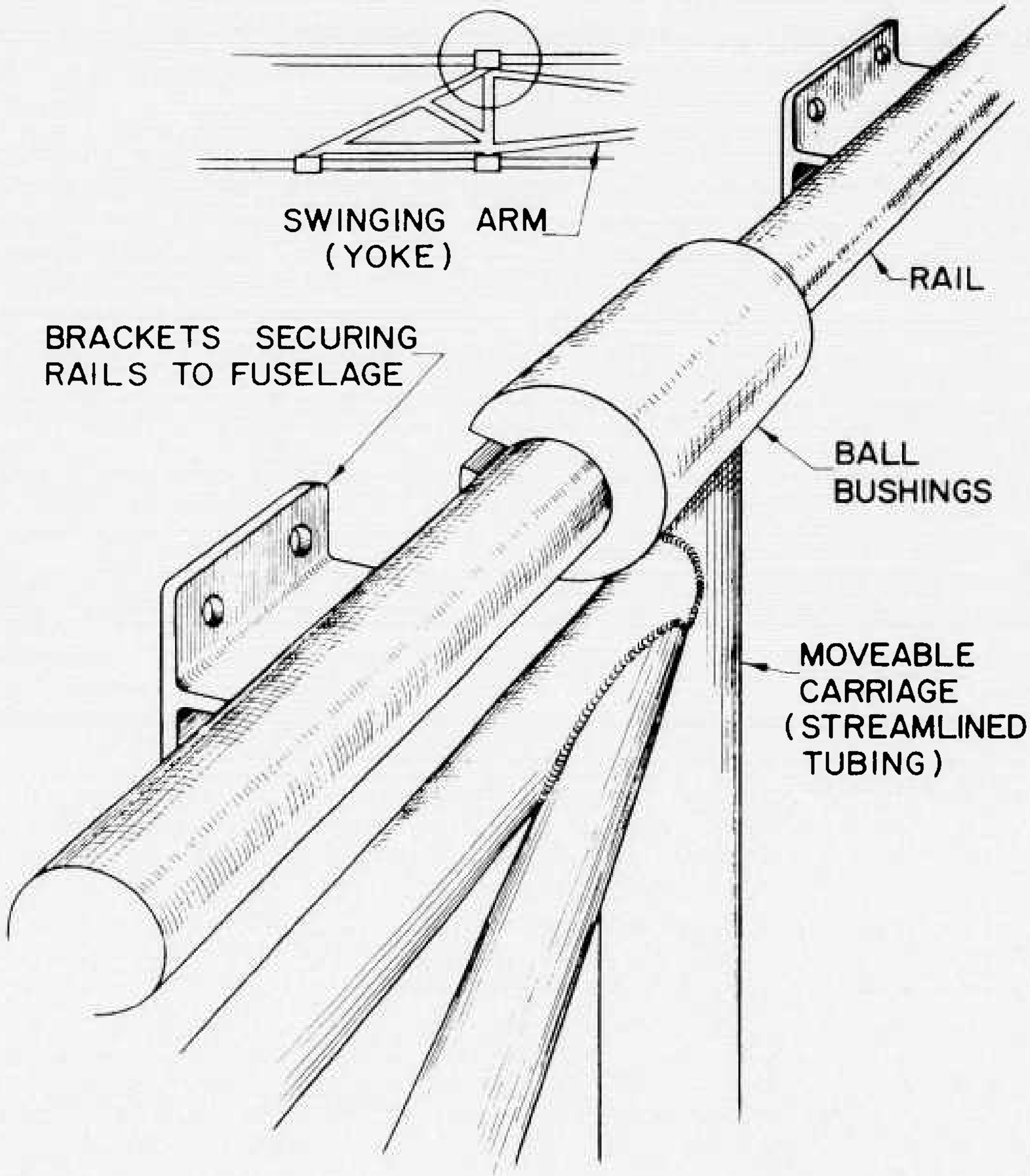



Figure 7. Typical Rail and Carriage Mounting Arrangement

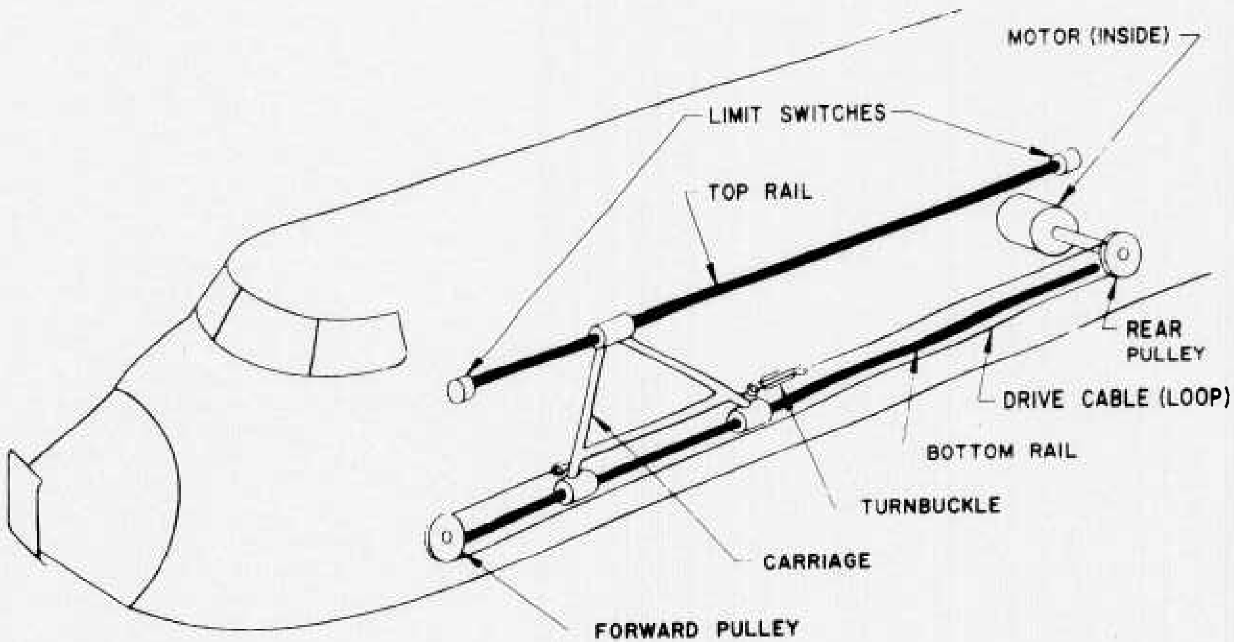



Figure 8. Possible Carriage Drive System (Electro-Mechanical)

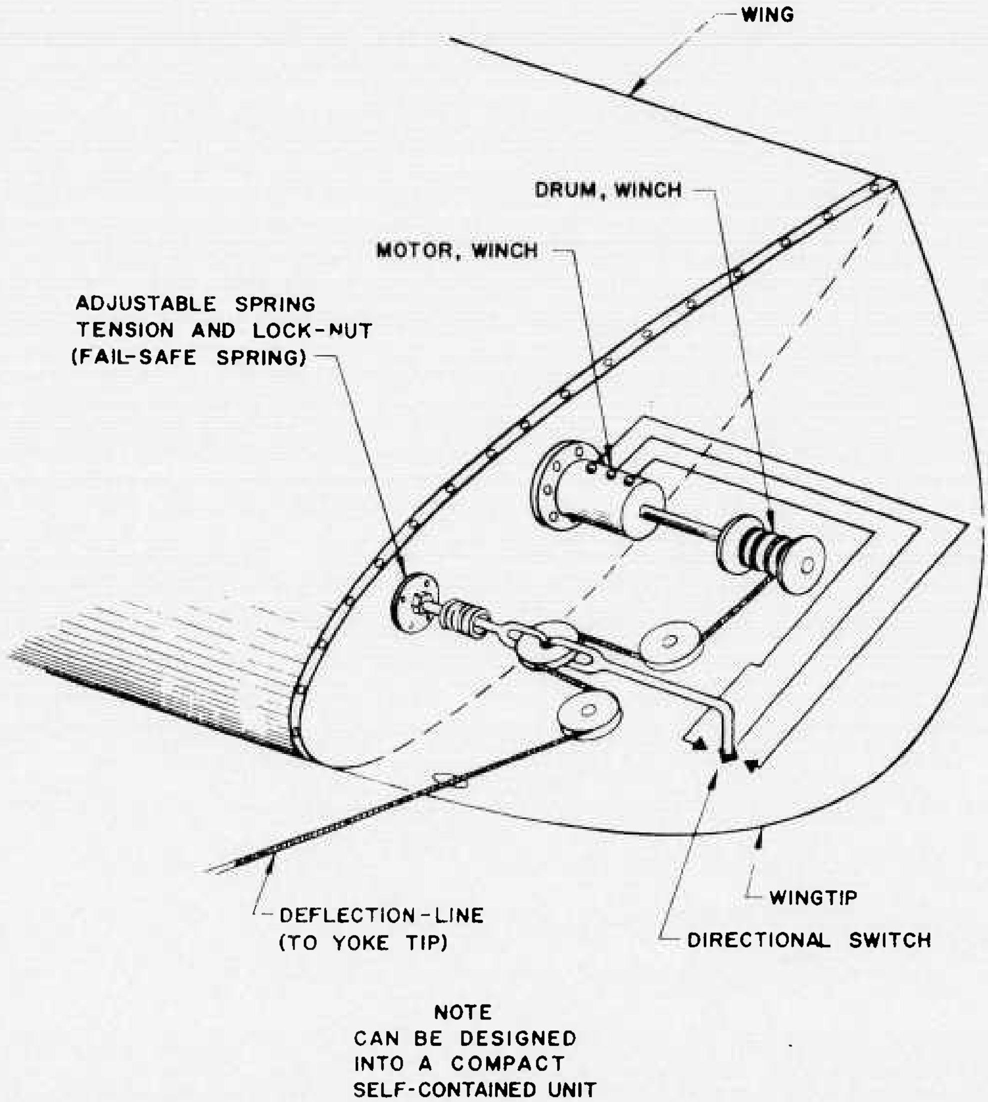



Figure 9. Constant-Tension Deflection-Line Winch

# CRITIQUE OF DESIGNS

## ARRANGEMENT A

Arrangement A is about as simple a design as is possible to make. There is only one rail, a simple mast, and a double-acting deflection-line. There is a minimum of parts, and the geometric action of the yoke can be accomplished by application of motive force at one point only (where the bearing slides along the track).

The arm, however, is long, and a clamping device will have to be provided at the point of attachment of the deflection-line to support the yoke rather than simply bend it back toward the wingtip.

In view of the close proximity of the attachment points on the side of the fuselage and the length of the members, this arrangement would have to be carefully checked for vibration.

## ARRANGEMENT B

If the constant-tension winch of Arrangement A failed to maintain the guide-line and deflection-line taut, then even if the pilot accomplished a satisfactory intercept, the lift-line could hang-up on a horn and never reach the skyanchor. The balloon would probably tear off, the lift-line fall to the ground, and the load remain where it is. To attempt another pickup, the pilot would have to land the aircraft and repair the constant-tension winch.

Arrangement B eliminates this situation by substituting a rigid member in place of the guide-line to guide the lift-line into the lock. Use of a rigid member is a considerable advantage, and the advantage is gained at the expense of adding only one more tube. Although the constant-tension winch would still be necessary to tighten the deflection-line, the deflection-line would come into action only in the remote case of a missed intercept. The worst that would be apt to happen <u>if</u> the deflection-line were limp and the pilot missed a satisfactory intercept would be a parting of balloon and lift-line. This would necessitate sending up another balloon, but would not require

landing the aircraft and repairing the winch. This appears to be an important advantage of Arrangement B over A.

## ARRANGEMENT C

While Arrangements A and B can possess good lateral support, they appear to be weak in the vertical plane. By adding an additional track to the side of the fuselage and thus providing a wide base between an upper and lower arm, considerable vertical support can be obtained.

By using a simple triangular carriage, motive power for the whole assembly can still be applied at a single point (the lower rear corner). This represents a considerable improvement over A and would also improve B.

Arrangement C again has the disadvantage of A with the double-acting deflection-line. A combination of B and C appears to be better than A or B or C alone.

## ARRANGEMENT D

Arrangement D provides even greater vertical support. The leading member of the yoke is doubled. However, because it pivots from the nose of the aircraft instead of sliding along a track, its shape is not as good for guiding the lift-line into the skyanchor; it has too flat an angle at the tips.

Arrangement D also lacks a deflection-line. In its place is a cutter-line. Such a cutter-line is considered a minimum solution, but in this instance it could be converted into a deflection-line simply by adding a sail track and halyard, which by their nature could be troublesome.

Arrangement D is a clean, neat solution if one chooses to disregard the chance of an occasional missed intercept.

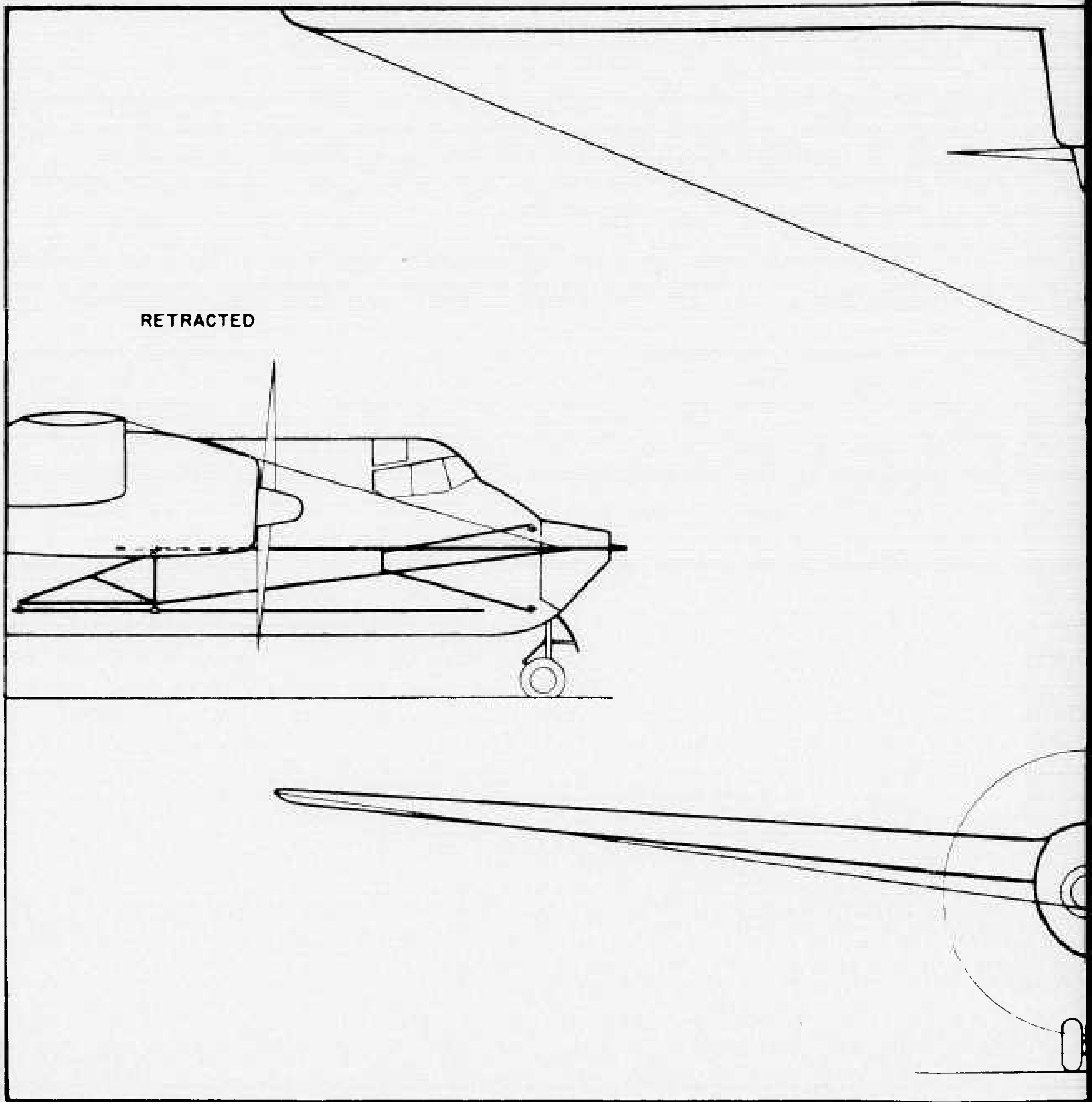
## FINAL ANALYSIS

There are a number of potential solutions to the problem of a folding yoke. Most promising appears to be a combination of Arrangements B and C, utilizing the tubular forward yoke member from B and the dual-track carriage from C. Figure 10 illustrates this arrangement.

In the final design and construction of such a unit, maximum advantage should be taken of streamlined tubing and aerodynamic shapes to reduce both drag and vibration.

A deflection- or cutter-line, preferably the former, must be incorporated in the design. It is entirely possible to include it, and no amount of statistical data concerning the small percentage of missed intercepts should affect the decision to provide this feature.

A folding yoke, by virtue of being constructed of movable parts, is of necessity going to be more expensive, more difficult to maintain, and more prone to troubles than a fixed one. Since the greater part of operational missions will not require the retractable feature, it is felt that the fixed yoke should also be retained.

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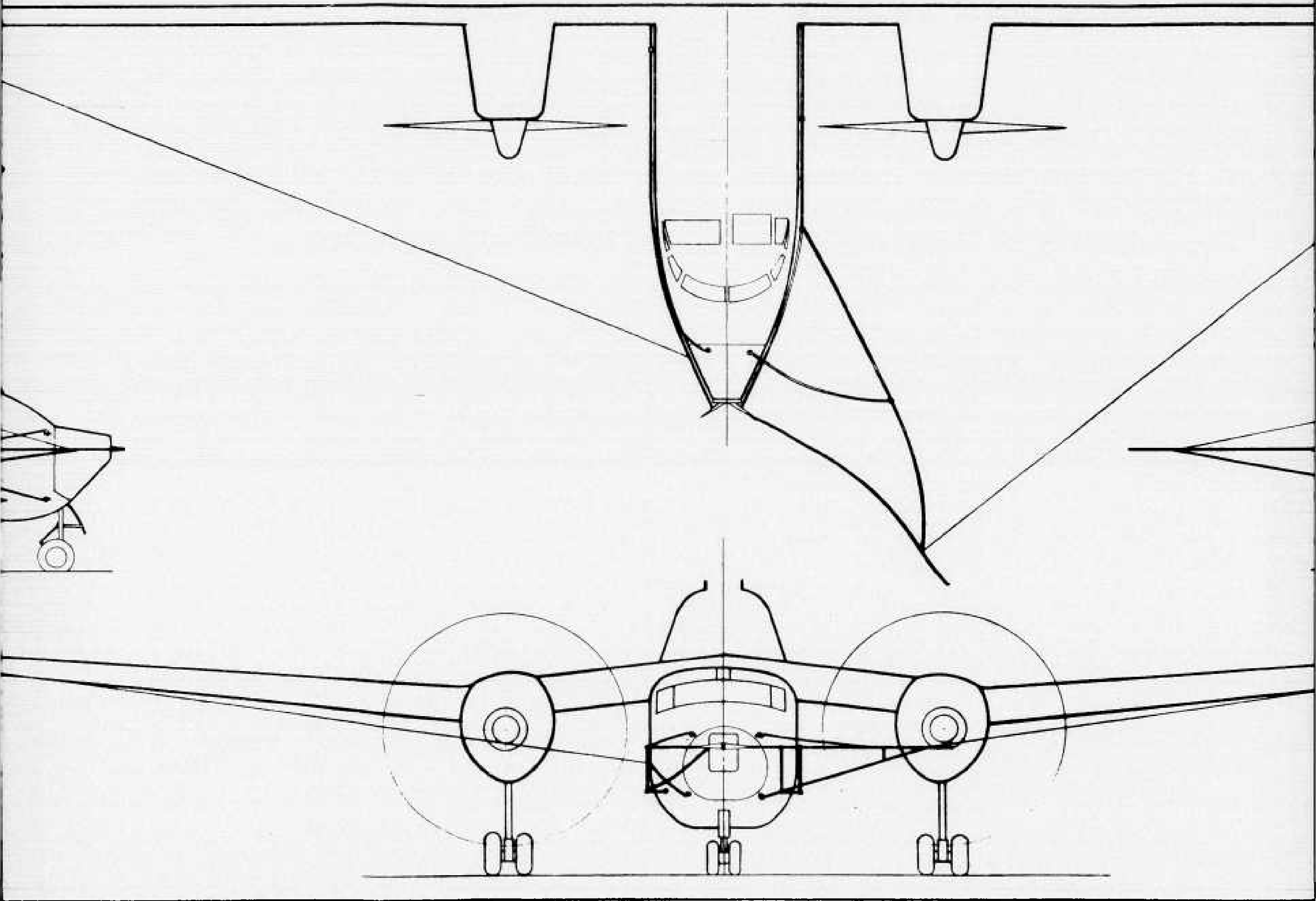

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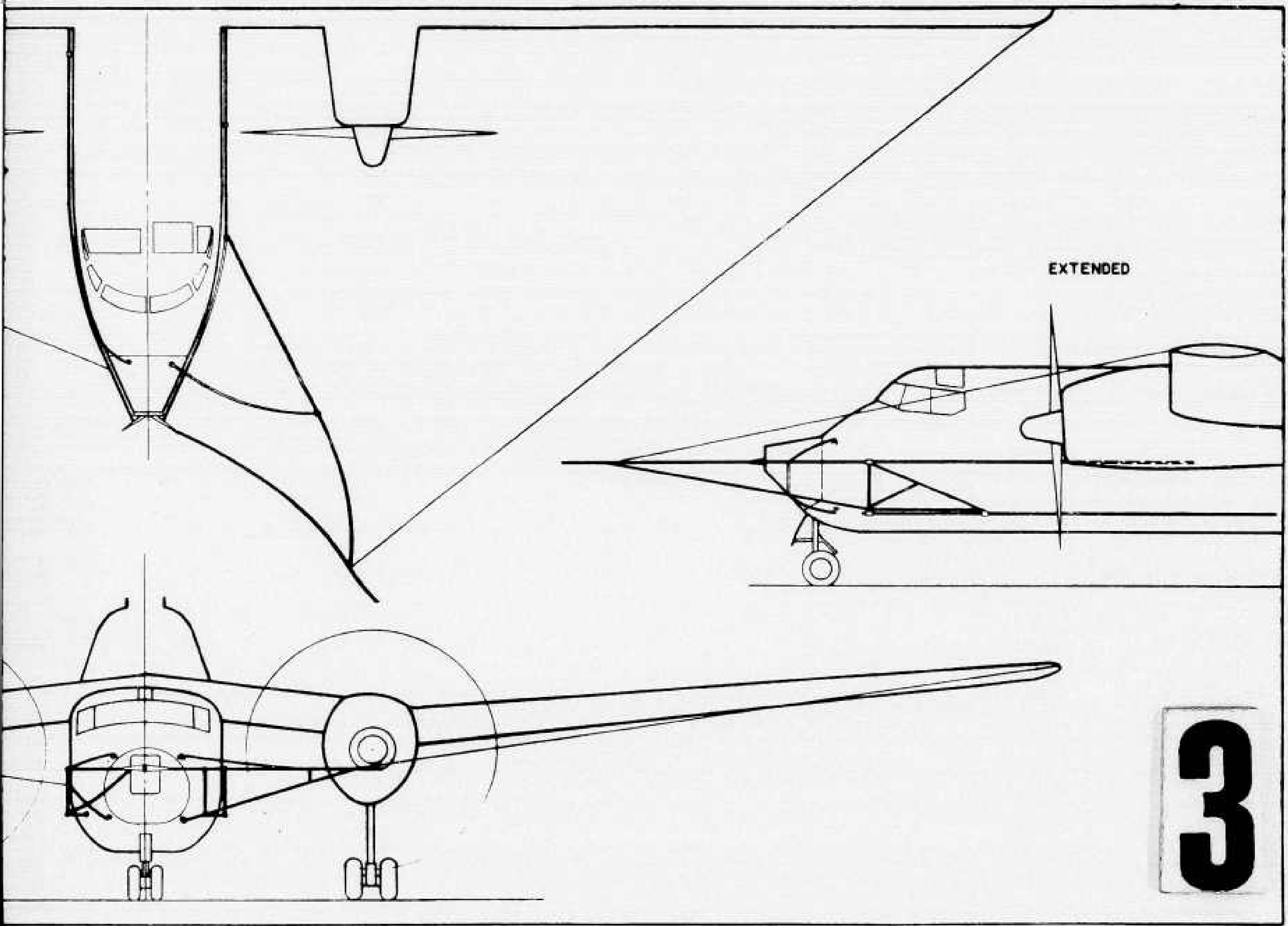


Figure 10. Arrangement E.

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Unclassified Report

A study of the feasibility of retracting the yoke of the Fulton SKYHOOK Air-to-Ground Recovery System installed on Army Type CV2B (Caribou) Aircraft. The recovery system is
(over)

1. Air-to-Ground Pickup
2. Fulton Skyhook Yoke
3. Fixed-Wing Aircraft Recovery System

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Robert Fulton Company, Newtown, Conn., RETRACTING THE FULTON SKYHOOK YOKE ON ARMY TYPE CV2B (CARIBOU) AIRCRAFT - Robert E. Fulton, Jr., May 1963, (Contract DA 44-177-AMC-891(T) USATRECOM Task 9R96-11-001-02. 30 pp incl. illus. tables. (TRECOM Technical Report 63-51)
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